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ECONOMIC IMPACT OF HESSIAN FLY ON SPRING WHEAT

Richard Smiley, Ruth Whittaker, Jennifer Gourlie, Karl Rhinhart, Erling Jacobsen, Sandra Easley, and Kimberlee Kidwell

Abstract

Economic damage caused by Hessian fly was quantified on three spring wheat experiments near Pendleton, Oregon during 2001. Genetic resistance or an insecticide each led to a doubling of grain yields for susceptible varieties, and improved grain market grades by up to two grades; e.g., test weight was increased as much as 2.8 lb/bu. Hessian fly therefore caused damage in excess of $70 per acre (20 bu/acre x $3.50/bu) without considering price discounts for reduced market quality. Genetic resistance is available at no additional input cost to the grower, compared to costs incurred through the use of chemical insecticides. The biology and control of Hessian fly are also summarized.

Key Words
Hessian fly, wheat, genetic resistance, root lesion nematode, insecticide.

Introduction

Hessian fly (*Mayetiola destructor*) is one of the most intractable insect pests of wheat in the United States (Morrill 1995). This insect causes economic damage to susceptible wheat varieties in Oregon during 1 of every 2 or 3 years. Spring wheat is much more heavily damaged than winter wheat, and both are subject to especially heavy damage in high-residue and annual cropping systems (Fisher et al. 1981, Pike and Antonelli 1981, Pike et al. 1993). Hessian fly adults are small mosquito-like flies with a life span of approximately 2 days. During that brief time they mate and the female lays about 200 eggs in the grooves on the upper side of wheat leaves. Eggs hatch and small larvae move along the groove to the leaf sheath and then to comparative safety between the leaf sheath and stem. Larvae suck sap from the stem above the leaf base and inject a toxin that stunts tillers and weakens the stem at the node where feeding occurred. The over-wintering and over-summering stage is a puparium that looks like a flax seed, located under the leaf sheath and just above a stem node. Damaged tillers often lodge at maturity. Even without lodging, Hessian fly-damaged plants produce less grain with reduced test weight compared to healthy wheat plants.

The Hessian fly is a cool-season insect with a life cycle that is heavily influenced by weather. Outbreaks occur sporadically and very rapidly. Flights of adults occur in the Pacific Northwest (PNW) at least three times annually, once during the autumn and twice during the spring. The flight during the autumn typically occurs before mid-October; however, if late summer rain occurs there may be two flights during the autumn instead of the usual one flight. The first spring flight occurs after the mean temperature reaches 45-50^{o}F. A second flight occurs during late May or June. Four to eight biotypes (races) of the Hessian fly occur in the PNW (Ratcliffe and Hatchett 1997; Ratcliffe et al. 2000; Dr. Steve Clement, USDA-ARS, Pullman, WA, personal communication 2001).

Experiments in the Oregon State University (OSU) plant pathology program at Pendleton provided opportunities to quantify economic damage caused by Hessian fly on spring wheat during crop year 2001. None of the experiments were designed for this purpose. Portions of two experiments are summarized to illustrate the impact of Hessian fly on spring wheat production.

Methods

Genetic Resistance

An experiment was designed to examine spring wheat cultivars and advanced breeding lines for differences in genetic resistance to Fusarium crown rot (Fusarium foot rot; *F. pseudograminearum*). The experiment was planted onto summer fallow following a winter wheat crop harvested during 1999 at the OSU Columbia Basin Agricultural Research Center (CBARC) at Pendleton. Dr. Kimberlee Kidwell (Washington State University [WSU]), who emphasizes selection for resistance to Hessian fly in her spring wheatbreeding program, provided 22 wheat entries for this experiment. Precipitation for the crop year (September 2000 through August 2001) was 16.5 inch at this site.

Wheat was planted into 5- by 20-ft plots with a John Deere HZ deep-furrow drill equipped with a cone-seeder and four openers spaced at 14 in. Each wheat entry was planted with and without supplemental inoculum consisting of five isolates of *F. pseudograminearum* collected from infected wheat crowns in Oregon and Washington. Procedures used for preparing and dispensing the fungal inoculum are not described since responses to Hessian fly damage are only reported for non-inoculated plots. Wheat seed was treated with benomyl (Benlate 50W; 0.72 oz/cwt) in accordance with accepted procedures to examine varietal responses to Fusarium crown rot. On March 20, wheat was planted at 25 seeds/ft^2 and 2.75-in depth into moist soil. Temperature in the seed zone at planting time was 52^{o}F. The experimental design (as adjusted to exclude inoculated plots) was a randomized complete block with four replicates. Hessian fly damage was noted during June. Samples were collected and plants were scored positive if at least one puparium was detected. Prematurely ripening (whiteheads) and total heads per row were counted in July and grain was harvested during August.

Variety x Insecticide Interaction

An experiment was designed to determine if root lesion nematodes cause economic damage. Spring wheat was planted into annually cropped fields at three locations, two in Umatilla County and one in Sherman County. The Sherman County experiment is not included in this report because drought confounded experimental variables and Hessian fly infestations were lower (30 percent of plants contained puparia) than at the other two locations. Experimental sites for this report include the CBARC, 8 miles northeast of Pendleton, and a commercial field (Mary Ann [Hill] Davis), 8 miles southeast of Pendleton. Each site is planted annually without tillage. Spring wheat followed 2 years of winter wheat at CBARC, and followed 1 year of canola that followed winter wheat at the Hill Farm. Precipitation for the crop year (September 2000 through August 2001) was approximately 16 inch at these sites.

Three spring wheat varieties in this experiment were selected because they are either resistant (‘Krichauff’ and ‘Sunvale’) or susceptible (‘Machete’) to root lesion nematodes in Australia. One PNW variety (‘Westbred 926’, Western Plant Breeders) and one from Mexico (‘Opata 85’; International Maize and Wheat Improvement Center [CIMMYT]) were included for comparison. ‘Westbred 926’ is known for having resistance to Hessian fly (Wash. State Crop Improvement Assoc. 2001 Certified Seed Buying Guide). Each variety was planted with or without Temik® 15G (Rhône-Poulenc) to assist in interpreting potential damage by nematodes. Aldicarb (Temik 15G) is an insecticide/nematicide that is not registered for use on wheat; all grain was therefore destroyed after harvest data were collected. Wheat was planted on March 20 into 5- by 20-ft plots with a John Deere HZ deep-furrow drill equipped with a cone-seeder and four openers spaced at 14 in. Temperature in the seed zone was 54°F at the time of planting. Temik was dispensed with the seed and applied at a rate of 25 lb/acre. Seed was treated with RTU Raxil-Thiram (Gustafson LLC). Starter fertilizer (mixture of 16-20-0-14) was metered from a Gandy box (at 10 lb N/acre) and was banded 1 inch below the seed. The experimental design was a split plot with wheat cultivar as the main plot and Temik treatments (plus or minus) as subplots in blocks replicated three times. Plants were evaluated for diseases during June, at which time it was noted that many plants were infested with Hessian fly. Plants were scored positive if they contained one or more puparia per plant. Grain was harvested during August.

Results and Discussion

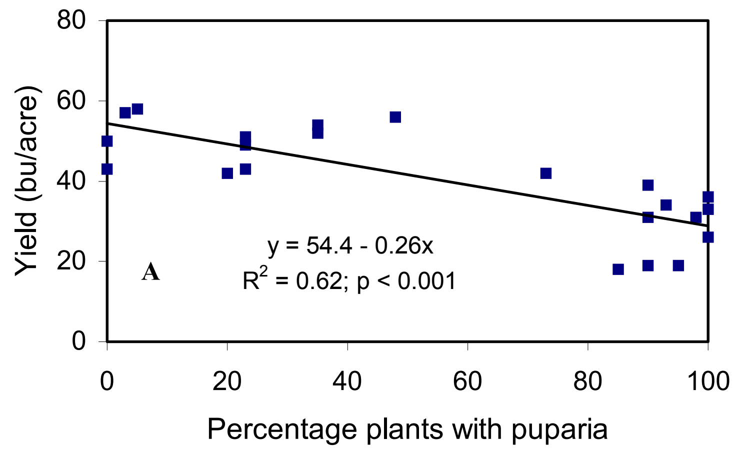
Genetic Resistance

Wheat entries in this test had highly divergent levels of resistance to Hessian fly, ranging from none to 100 percent. Entomologists score this insect more precisely on the basis of numbers of puparia per infested tillers, rather than presence or absence of one or more puparia per whole plant. That precise procedure was beyond the scope of work in our pathology program. Plant growth and grain yield were strongly reduced by Hessian fly (Table 1).

Table 1. Influence of Hessian fly on development of whiteheads, grain yield, and grain quality in spring wheat varieties and breeding lines at Pendleton, Columbia Basin Agricultural Research Center, during 2001.

Wheat entry	Plants with one or more puparia	White-heads	Grain yield	Test weight	Market grade
	percent	*percent*	*bu/acre*	*lb/bu*	*US No.*
Macon	0	3	50	58.3	1
WA 7894	0	2	43	59.1	1
WA 7877	3	1	57	58.7	1
Zak	5	2	58	57.5	2
WA 7892	20	1	42	57.9	2
WA 7906	23	1	51	58.3	1
WA 7893	23	1	49	58.9	1
Tara	23	1	43	58.6	1
WA 7905	35	1	54	58.9	1
WA 7887	35	1	52	58.9	1
WA 7890	48	2	56	57.4	2
WA 7904	73	3	42	56.7	3
WA 7902	85	7	18	59.4	1
WA 7910	90	5	39	58.8	1
WA 7886	90	3	31	56.0	3
Calorwa	90	8	19	52.7	5
Scarlet	93	3	34	58.3	1
WA 7900	95	5	19	57.1	2
WA 7883	98	6	31	56.3	3
WA 7901	100	5	36	54.8	3
WA 7907	100	3	33	57.4	2
WA 7914	100	4	26	58.3	1
LSD (p = 0.05)	37	4	9	2.7	-
CV (%)	47	93	16	3	-
P (>F)	<0.001	0.003	<0.001	0.001	-

Grain yield was highly correlated (Fig. 1A) with percentages of plants infested by Hessian fly ($p < 0.001$, $R^2 = 0.62$). The plot of data in Figure 1A suggested that there may be a critical level of infestation above which yield is depressed. This possibility was assessed by bracketing the data into quadrants and then moving the vertical and horizontal dividing lines to approximate the percentage at which yield declined rapidly (Fig. 1B). The bracketed data suggest that for this experiment, damage became particularly acute when at least one puparium was present in more than 80 percent of the plants.



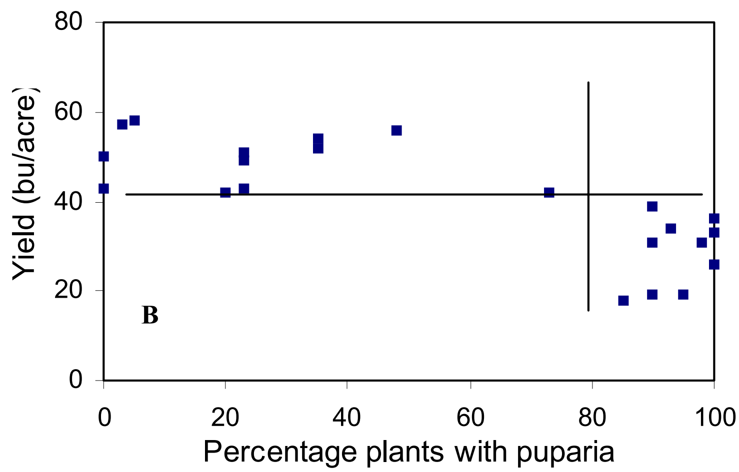
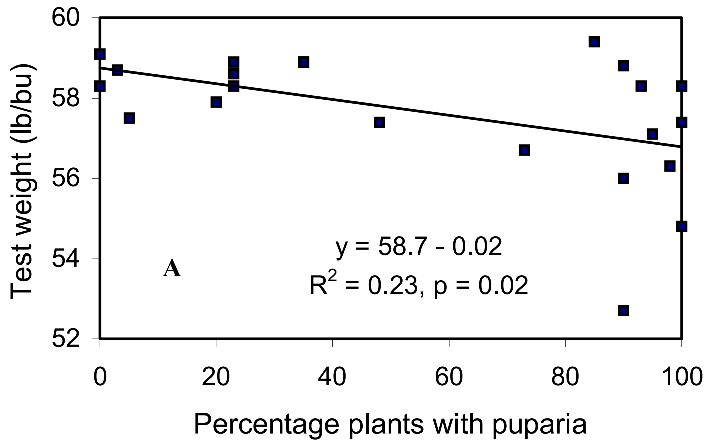


Figure 1. Effects of Hessian fly infestation on yield of 22 spring wheat varieties and lines at the Columbia Basin Agricultural Research Center, 2001; (A) linear regression of yield and level of infestation, (B) data bracketed to illustrate the infestation rate at which yield potential was strongly suppressed.

Test weight was also correlated with percentages of plants infested by Hessian fly (Fig. 2A). Bracketed data also indicated that test weights for some wheat entries became unstable and declined when more than 80 percent of plants were infested (Fig. 2B).



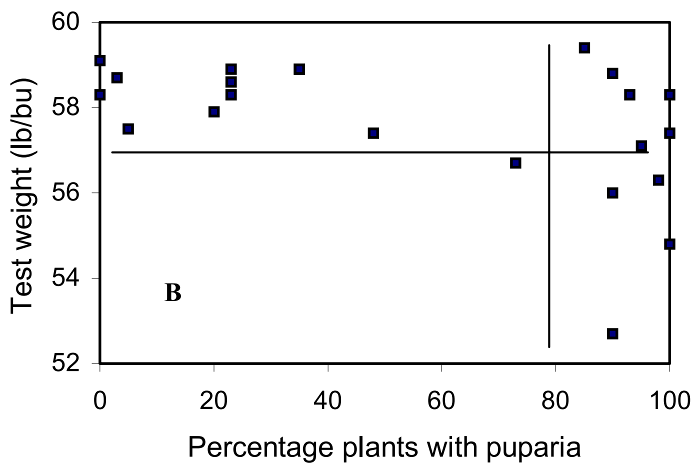
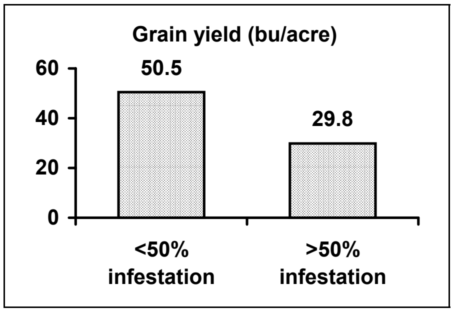


Figure 2. Effects of Hessian fly infestation on test weight of 22 spring wheat varieties and lines at the Columbia Basin Agricultural Research Center, 2001; (A) linear regression of test weight and level of infestation, (B) data bracketed to illustrate the infestation rate at which test weight became unstable and, for some entries, became strongly suppressed.

Another way to evaluate damage by Hessian fly is to compare average yields and test weights for entries having either more or less than 50 percent infested plants. Eleven entries with less than 50 percent infested plants yielded 69 percent more grain than eleven entries with more than 50 percent infested plants: 50.5 vs. 29.8 bu/acre (Fig. 3). Those same groups of plants had average test weights of 58.4 and 56.9 lb/bu, respectively, suggesting that Hessian fly had a strong limiting influence on grain quality



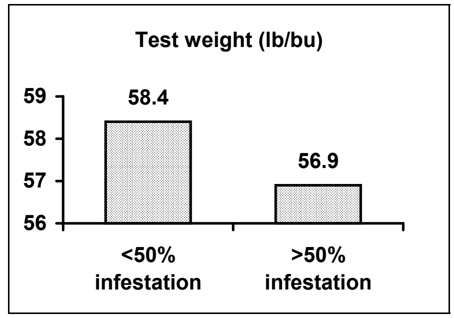


Figure 3. Comparison of grain yield and test weight for two groups of 11 spring wheat entries that had one or more Hessian fly puparia in less than or more than 50 percent of the plants, Columbia Basin Agricultural Research Center, 2001.

by reducing the wheat marketing grade from No. 1 to No. 3.

Whiteheads occurred on many tillers infested by Hessian fly. The regression equation and significance of this relationship were: yield = 50.02 bu/acre – 0.23 (percent infested plants); $r^2 = 0.41$; $p < 0.001$; n = 120. Although the regression includes wheat entries that differ in yield potential, the equation indicates that yield is reduced by nearly one-quarter bushel for each percentage of plants infested by the fly.

Variety x Insecticide Interaction

High levels of Hessian fly were recorded at both sites. A maximum of 12 puparia per tiller were observed at CBARC, where the fly caused extensive lodging. About 90 percent of the susceptible varieties contained at least one puparium under the leaf sheath of one or more tillers when plants approached maturity at both locations (Table 2). In contrast, 'Westbred 926' had no puparia in plants at the Hill Farm and only 10 percent of plants at CBARC had puparia. Percentages of plants with Hessian fly puparia were significantly different among varieties at both locations, with the primary difference being that 'Westbred 926' was resistant and the other four varieties were susceptible. Temik strongly improved foliar growth and tiller density throughout the season at CBARC, and reduced lodging at both locations at the end of the season. However, the insecticide/nematicide did not reduce final fly infestation rates, as assessed by puparia present on plants late in the growing season. This indicates that the insecticide did not greatly reduce over-summering or over-wintering populations capable of emerging for the autumn or spring flight.

'Westbred 926' had higher grain yields than the four other varieties. The other varieties were therefore grouped for this report. Yield improved 4 to 7 percent when Temik was applied to 'Westbred 926' (Table 2). Yields for the group of susceptible varieties were improved 44 percent and 105 percent by applying Temik at the Hill Farm and at CBARC, respectively. The yield benefit from genetic resistance was far less when Temik was applied (26 to 22 percent) than when not applied (45 to 60 percent).

The small positive yield response to Temik in 'Westbred 926' may have been from reduction in damage by nematodes, wireworm, other insect pests, or from incomplete resistance to Hessian fly biotypes present at these locations. However, Temik induces hormonal effects

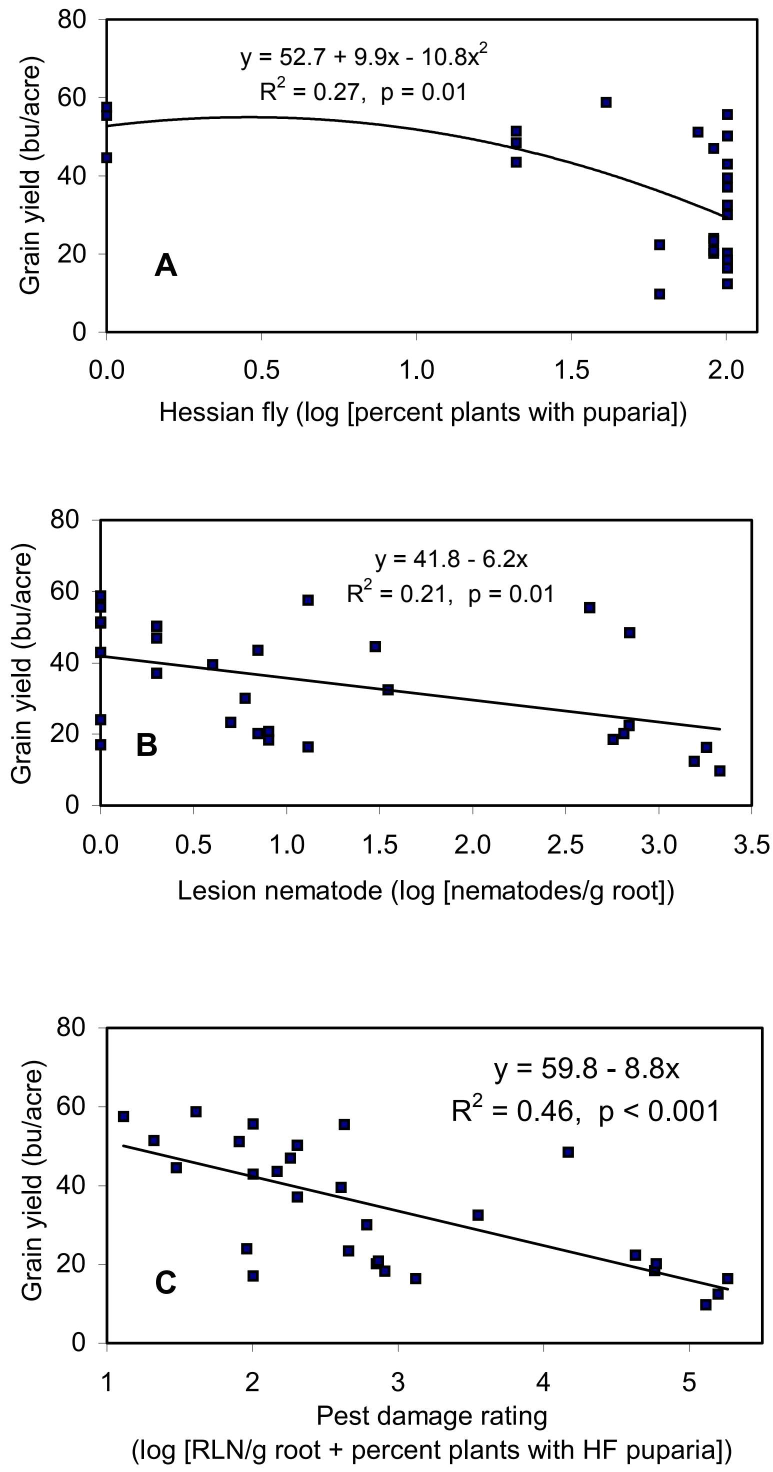


Figure 4. Relationship of spring wheat yield to Hessian fly infestation (A), root lesion nematode (B), and combined effects of damage from Hessian fly and lesion nematode (C), in a factorial that are capable of imparting small growth-enhancing effects in the absence of pests, which could confound interpretation of results. Nevertheless, it was very clear that the principal yield-promoting influence of Temik in this experiment was through pesticidal effects because differences in yield were far greater on the group of Hessian fly-susceptible varieties (44 to 105 percent) than the Hessian fly-resistant variety (4 to 7 percent).

Yield data in this factorial experiment with five varieties treated or not treated with Temik could be explained more fully by regressing yield against a combined damage rating function for Hessian fly plus lesion nematodes (Fig. 4C: 46 percent of yield explained) than for individual functions for Hessian fly (Fig. 4A: 27 percent of yield) or lesion nematode (Fig. 4B: 21 percent of

Test weight also improved 2 to 3 lb/bu when Temik was applied to 'Westbred 926' (Table 2). U.S. grain marketing requirements are strongly influenced by test weight. Minimum standards for hard red spring

yield). The combined function was improved to 50 percent when data were plotted on a log-log axis rather than the log-linear axis shown in Figure 4. We conclude that both pests were important constraints to grain yield in this experiment.experiment including five varieties planted with or without aldicarb insecticide at the Columbia Basin Agricultural Research Center, 2001. wheat and white club are 58 lb/bu for No. 1, 57 lb/bu for No, 2, 55 lb/bu for No. 3, 53 lb/bu for No. 4, and 50 lb/bu for No. 5 (Subpart M, United States Standards for Wheat;

Table 2. Influence of Temik®, applied with seed at the time of planting, on numbers of Hessian fly puparia, grain yield, and test weight for resistant ('Westbred 926') and four susceptible (all others) varieties of spring wheat.

Location and varieties	**Mature plants with one or more puparia**		**Grain yield**			**Grain test weight**		
	Control	**Temik**	**Control**	**Temik**	**benefit**	**Control**	**Temik**	**benefit**
	percent	*percent*	*bu/acre*	*bu/acre*	*percent*	*lb/bu*	*lb/bu*	*lb/bu*
Hill Farm								
Westbred 926	0	0	29	31	7	55.5	58.3	2.8
Other 4 varieties	99	88	16	23	44	55.3	57.4	2.1
Krichauff	*100*	*80*	*21*	*34*	*62*	*55.1*	*58.2*	*3.1*
Machete	*97*	*90*	*10*	*13*	*30*	*53.6*	*54.8*	*1.2*
Opata 85	*100*	*90*	*20*	*25*	*25*	*56.6*	*57.6*	*1.0*
Sunvale	*97*	*93*	*14*	*19*	*36*	*55.8*	*58.8*	*3.0*
Reduced yield and test weight			45%	26%	-	0.2	0.9	-
CBARC								
Westbred 926	7	13	48	50	4	57.0	58.9	1.9
Other 4 varieties	91	92	19	39	105	54.7	56.1	1.4
Krichauff	100	73	26	51	96	57.0	55.7	-1.3
Machete	87	23	13	22	69	52.4	54.5	2.1
Opata 85	83	97	18	40	122	54.1	55.1	1.0
Sunvale	93	97	18	41	128	55.4	59.1	3.7
Reduced yield and test weight			60%	22%	-	2.3	2.8	-

http://usgmrl.ksu.edu/gqu/HWWQL/wheat_ stds.htm). For all varieties except 'Machete', the market grade was improved at both locations by one or two grades through application of Temik. The benefit of genetic resistance was also clear. 'Westbred 926' ranked two to three market grades higher than all other varieties except 'Krichauff' (without Temik) and 'Sunvale' (with Temik) at CBARC. Benefits of resistance were less clear at the Hill Farm, where 'Westbred 926' and all other varieties graded U.S. No. 3 or lower in the absence of Temik, and all except 'Machete' were improved one or two grades by application of Temik.

Summary

Data from experiments near Pendleton indicated that spring wheat yields and test weights could have been improved by employing strategies for controlling damage from the Hessian fly during 2001. Overall yields were improved by about 20 bu/acre where either genetic resistance or chemical control strategies were employed. There did not seem to be a strong benefit from applying both genetic and chemical controls, although that was useful where nematodes as well as Hessian flies caused damage. The combination of genetic resistance and insecticide could also be important for protecting varieties with incomplete resistance to the biotypes of Hessian fly present. Likewise, test weights were improved by up to 2.8 lb/bu where damage from the Hessian fly was limited by genetic resistance or chemical control. The gross economic benefit attained by reducing Hessian fly damage equated to as much as $70 per acre ($3.50/bu x 20 bu/acre). There is an inherent advantage to using genetic resistance for insect control in that it comes at no additional input cost to the grower compared to costs incurred through the use of chemical control measures. Improved test weight attained by controlling fly damage would further influence income; test weights in damaged wheat were moved downward by as many as two marketing grades in our experiments.

Acknowledgements

We wish to thank Mary Ann (Hill) Davis for hosting an experiment reported in this paper. We also thank Drs. Steve Clement (USDA-ARS, Pullman) and Dave Bragg (WSU, Pomeroy) for providing helpful suggestions and editorial oversight. This research was funded through a Specific Cooperative Agreement between Oregon State University and USDA-Agricultural Research Service: CSA 58-5348-9-100 "*Control of Root Diseases of Wheat and Barley*".

Precaution

Application of Temik® to small grain cereals is inconsistent with the product label, and therefore illegal for commercial wheat production. Application of Temik to wheat in this experiment was for research purposes only. All grain produced in the study was destroyed.

References

Pike, K., R. Veseth, B. Miller, R. Schirman, L. Smith, and H. Homan. 1993. Hessian fly management in conservation tillage systems for the inland Pacific Northwest. PNW. Conservation Tillage Handbook Series, Chapter 8, No. 15. 5 pages.

Fisher, G., K. Pike, R. Rickman, and D. Maxwell. 1981. The Hessian fly in Oregon. Oregon State University Extension Circ. 1093. 4 pages.

Morrill, W.L. 1995. Insect pests of small grains. APS Press, St. Paul, MN. 140 pages.

Pike, K.S., and A.L. Antonelli. 1981. Hessian fly in Washington. Washington State University Research Center, Pullman. 12 pages.

Ratcliffe, R.H., and J.H. Hatchett. 1997. Biology and genetics of the Hessian fly and resistance in wheat. Pages 47-56 *in* K. Bondari (ed.). New Developments in Entomology. Research Signpost, Scientific Information Guild, Trivandrum, India.

Ratcliffe, R.H., S.E. Cambron, K.L. Flanders, N.A. Bosque-Perez, S.L. Clement, and H.W. Ohm. 2000. Biotype composition of Hessian fly populations from the southeastern, Midwestern, and northwestern United States and virulence to resistance genes in wheat. Journal of Economic Entomology 93:1319-1328.

Management Strategies for Hessian Fly

Spring Wheat

Management practices for spring wheat include: (1) planting a fly-resistant variety, (2) controlling volunteer wheat and grass weeds from the time they germinate in the fall until the new crop is planted in the spring, (3) planting as early as possible, (4) rotating wheat with non-host crops such as legumes or canola, and/or (5) applying an insecticide at planting, either through a seed treatment or using a registered product in-furrow with the seed. Adapted resistant varieties currently available or in the certified seed increase process include the soft white spring varieties ‘Wakanz’, ‘Wawawai’, and ‘Zak’, as well as the hard red spring varieties ‘Westbred 926’, ‘Hank’, and ‘Tara’. Washington State University’s first hard white spring wheat variety release, ‘Macon’ (WA 7899) also is resistant to the Hessian fly. Insecticides currently registered for seed treatment include Cruiser® and Gaucho®. Insecticides registered for application in-furrow below or with the seed include Di-Syston®, Phorate®, and Thimet®. Damage to spring wheat is greater in high-residue or no-till seedbeds particularly if preceded by another susceptible crop. Hessian fly is less damaging to winter wheat, spring barley, and triticale than to spring wheat.

Winter Wheat

Although winter wheat is generally less affected than spring wheat, specific management practices for winter wheat may become required in some areas. Damage to winter wheat can be reduced by (1) planting after October 15, (2) controlling volunteer wheat and grass weeds through the summer, (3) reducing the level of surface residues from previous susceptible crops, (4) rotating with non-host crops such as legumes or canola, (5) planting a fly-resistant variety; and/or (6) applying an insecticide at planting either by treating seed or placing a registered product in the furrow with the seed. Winter barley and triticale are less susceptible than winter wheat.

All Wheat

Growers and crop advisors also must scout fields to evaluate the performance of varieties that are currently resistant to the Hessian fly. This fly occurs as a mixture of biotypes (“races”), which are either virulent or avirulent to individual genes for resistance in wheat. Deployment of new resistance genes is required to maintain levels of genetic resistance currently available. Four to eight biotypes are currently present in the PNW (Dr. Steve Clement, USDA-ARS, Pullman; personal communication, 2001). Several biotypes that are not present in high proportions of the total population are virulent to resistance genes currently deployed in resistant spring wheat varieties. A shift in dominance of biotypes, or the entry into the region by new biotypes could defeat the genetic resistance currently available. Wheat breeders and entomologists are well aware of this possibility and are working hard to identify biotypes and employ genes with resistance to current and newly emerging threats to the wheat industry.